SECTION 6- FIRE SUPPRESSION & DETECTION
UNIT 2 - PRINCIPLES OF WATER SUPPLY

UNIT GOAL

To introduce the student to the basic theories and concepts regarding water as an extinguishing agent and types of water supply systems that allows the movement of water for fire protection needs. The types and uses of standpipe systems will be discussed.

UNIT OBJECTIVES

The student by the end of the semester shall:

- List two [2] physical properties of water
- List two [2] natural laws that affect the extinguishing properties of water
- List at least three [3] disadvantages of water as an extinguishing agent
- Define the following terms
  - Atmospheric pressure
  - Static pressure
  - Residual pressure
- Define the term standpipe
- List the three [3] classes of standpipes
- Define the term hydrologic cycle
- List two [2] sources of water supply
- List three [3] types water supply systems
- List three [3]factors that affect the carrying capacity of pipes
- List two [2] types of fire hydrants

KEY TERMS

Specific Heat
Latent Heat of Vaporization
Pound Per Square Inch [PSI]
The Six Principles of Pressure
Atmospheric Pressure
Static pressure
Residual Pressure
NFPA Standard 14
Dry Barrel Hydrant
Wet Barrel Hydrant
Gravity Type Water System
Direct Pumping Water System
Combination Water System
Friction Loss
Normal Operating Pressure
Class I Standpipe System
Class II Standpipe System
Class III Standpipe System
Primary Type Feeders
Secondary Type Feeders
Distribution Lines
Hydrologic Cycle

INTRODUCTION

The primary extinguishing agent used in fire protection is water. Water consists of 2 atom of Hydrogen and 1 atom of Oxygen. If we look at water from an historical aspect, we see that it has been the extinguishing agent of choice for tens of thousands of years. It has several advantages that make it a desirable extinguishing agent, but it also has several disadvantages that make it limited on certain types of burning material. Water supply needs for fire protection may be enormous depending on the size of the fire. Because of this the water supply system must be large enough to fulfil this need. Municipal water system were in existence during the time of the Roman Empire, but fell into disuse during the "Dark Ages". Modern water supply systems trace their roots to the early 19th century. The modern water supply system provides two needs - water for fire protection and water for drinking, sanitary, and industrial applications. These modern water supply systems must be large enough to meet both of these needs comfortably. The design of water supply systems must consider the current situation and any future needs due to the expansion of the municipality.

In this unit we will discuss the physical properties of water, the advantages and disadvantages of water and the way that water is moved through pipes and hose using pressure as well as the different types of water supply systems and some of the components of them. We will also discuss the types and operating features of the fire hydrant.

PHYSICAL PROPERTIES OF WATER

Water is made up of two atoms of Hydrogen and one atom of Oxygen. Water is a heavy stable liquid with a weight of 62.5 lbs/ft^3. It takes 7.5 gallons of water to equal one cubic foot space, and one gallon of water weighs 8.34 pounds. Water is non-compressible liquid. Water exists in three states:**[See Figure 1]**

- Solid - ice: below 32 deg. F.
- Liquid - water: above 32 deg. F. & below 212 deg. F.
- Gas - vapor: above 212 deg. F.

Water when converted to steam will expand 1600 to 1700 times its original volume.

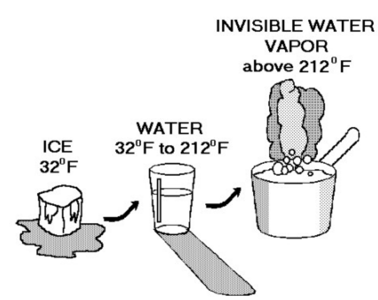

Figure 1 - Three States of Water

EXTINGUISHING PROPERTIES OF WATER

Water's effectiveness as an extinguishing agent is impacted by affected by two natural laws. These are ***Specific Heat*** and the ***Latent Heat of Vaporization***.

Specific Heat

Specific Heat is defined as the heat absorbing capacity of a liquid and .the ratio between the amount of heat needed to raise the temperature of a specified quantity of material and the amount of heat needed to raise the temperature of an identical quantity of water by the same number of degrees. Since water is non-combustible it is able to absorb large amounts of heat. It takes five times as much heat to raise the temperature of 1 pound of water 1 degree F. As it does 1 pound of CO_2. This makes water a better extinguishing agent due to its greater heat absorbing abilities.

Latent Heat of Vaporization

Latent Heat of Vaporization is defined as the quantity of heat absorbed by a substance when it changes from a solid to a liquid or a liquid to a vapor. The significance of this is waters ability to absorb large amounts of heat. Water will absorb 9000 Btu's per gallon when it is converted to steam. This means that 1 gallon of water will absorb the heat given off by 1 pound of wood (8000 Btu's) when it burns.

Another thing to consider is the relationship of the surface area of water to the amount of heat absorbed. The more surface area of water that is exposed to the heat the more heat it will absorb. When water is applied to a burning area in a spray form (or a large surface area) it will absorb a vast amount of heat and extinguish the fire. The steam cools the material and expels the oxygen from the area, thus smothering the fire.

ADVANTAGES AND DISADVANTAGES OF WATER

Water is by far the agent of choice when there is a need to control a fire. It has certain advantages, as well as, certain disadvantages. Some of these are listed below.

Advantages

- Greater heat absorbing capacity than other material
- Large amounts of heat are required to convert water to steam, so more heat will be absorbed from the fire
- The more surface area exposed to heat the more heat will be absorbed
- Water when converted to steam expands 1600 to 1700 times its original volume

Disadvantages

- High surface tension
  - This is limits water from soaking into tightly compacted fuels in order to extinguish deep seated fires
- Reactivity with other materials
  - water will react with certain fuels that may cause an explosive reaction.
  - Certain types of metals, i.e., magnesium or sodium react violently to the application of water.
- Low opacity
  - Water is basically transparent and so it will allow radiant heat energy to pass through it.
  - This limits water as an effective barrier to heat when it travels from a hot surface to a cooler surface.
- Low reflectivity
  - Similar to low opacity
- Freezing temperature
  - Since water freezes at 32 degrees F. It can cause damage to firefighting equipment [hose, pumps, hydrants] and is also a potential safety hazard to emergency service personnel during emergency operation in below freezing weather.
- Low viscosity.
  - Viscosity is defined as - a quantity expressing the magnitude of internal friction in a fluid, as measured by the force per unit area resisting uniform flow.
  - This limits water's ability to stick to the surface of a material, in particular, vertical surfaces. As a result water must constantly be applied to protect a surface from being heated.
- Electrical conductivity

- Water conducts electricity very readily. In areas of charged electrical equipment water can be a major hazard to emergency service personnel.

WATER PRESSURE AND VELOCITY

Pressure is defined as the force per unit area (pounds per square inch (psi)). In order to move water from it source to a point where it can be applied to a fire requires the use of pressure. There are six principles of pressure that impact water movement through pipes, hose, pumps, and nozzles. They are listed below

Six principles of pressure

- First principle of pressure -fluid pressure is perpendicular to any surface on which it acts
    - Since pressure is applied at right angles to any surface it would hold that when applied to a surface in any other direction the water would move downward along the dides or rise towards the center
- Second principle of pressure -fluid pressure at a point in a fluid at rest is the same intensity in all directions
    - Based on this principle when pressure is applied to a container with water in it that is flat, the container would take the shape of a cylinder.
- Third principle of pressure -pressure applied to a confined liquid from without is transmitted equally in all directions
    - If we attached gauges to a cylinder filled with water and applied this principles all the gauges would read the exact same pressure, assuming that there is no movement of the water
- The fourth principle of pressure -the pressure of a liquid in an open vessel is proportional to its depth **[See Figure 2]**
    - Since a column of water 1 foot high exerts a pressure of .434 psi at it base, we can assume that a 10 foot column will exert 4.34 psi at its base. And that a column of water 100 feet high will exert a pressure of 43.4 psi at its base
    - If a 1 foot column of water exerts .434 psi, then a 2.31 foot high column of water will exert 1 psi at its base.
    - this is the principle that explains why we have to add extra pressure when we pump water up through a standpipe to an upper floor in a building.
- The fifth principle of pressure -the pressure of a liquid in an open vessel is proportional to the density of the liquid **[See Figure 3]**
    - Certain liquids have a greater density, and therefore exert a greater pressure with less depth. Mercury is an example. A one inch column of mercury will apply the same pressure as a 13.55 inch column of water.
- The sixth principle of pressure -the pressure of a liquid on the bottom of a vessel is independent of the shape of the vessel **[See Figure 4]**
    - Pressure is directly related to elevation, not size. Two columns, one square with a n area of 100 square feet and one oval with an area of 10 square feet, but the height is 100 feet will exert the exact same pressure at the base of the column.

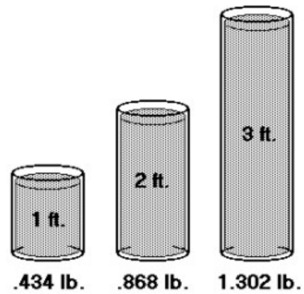

Figure 2 - 4th Principle of Pressure

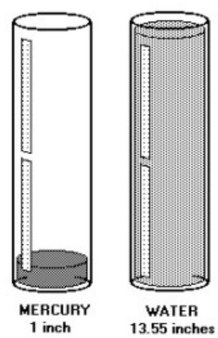

Figure 3 - 5th Principle of Pressure

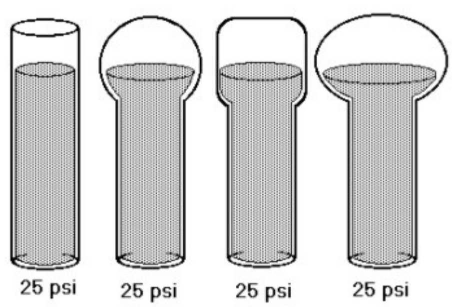

Figure 4 - 6th Principle of Pressure

Types of Pressure
Atmospheric pressure
The atmosphere exerts 14.7 psi is the pressure exerted by the air surrounding earth at sea level. As we go up in elevation the pressure decreases. As a result it becomes more difficult to maintain the combustion process and to breathe at elevated points. Any pressure below atmospheric is a vacuum. There are two terms used to indicate pressure.
Static pressure -
This is stored potential energy that is available to force water through pipes, fittings, fire hose and adapters.. In other words static pressure is no movement of water. **[See Figure 5]**
Normal operating pressure
That pressure which is normally found on a water distribution system during normal consumption demands. From the practical standpoint of fire protection this is the equivalent of static pressure. The reason is that there is always movement of water somewhere in the water system [hydrant opening, washing machine filling, leak in a pipe] **[See Figure 6]**
Residual pressure
That part of the total available pressure that is not used to overcome friction or gravity while forcing water through pipes, fittings, fire hose and adapters. This is the amount of water pressure left after we deduct for elevation, nozzle pressure, and friction loss.**[See Figure 7]**
Flow pressure [See Figure 8]
The forward velocity pressure at a discharge opening indicated by a pitot tube and gauge while water is flowing. Also called velocity pressure.. From a fire protection standpoint we call this nozzle pressure. By determining the nozzle pressure we can, via formula, determine how much water is is being flowed.
Friction loss
That part of the total pressure lost while forcing water through pip, fittings, fire hose and adapters . Friction loss is based on flow, the greater the flow the greater the friction loss.. Friction is affected by distance, if the length of a pipe or hose is doubled in length so is the friction loss.

Figure 5 - Static Pressure

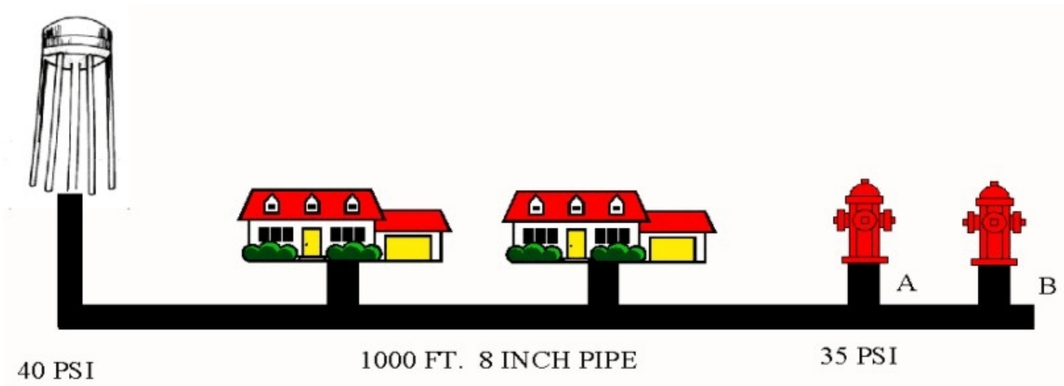

Figure 6 - Normal Operating Pressure

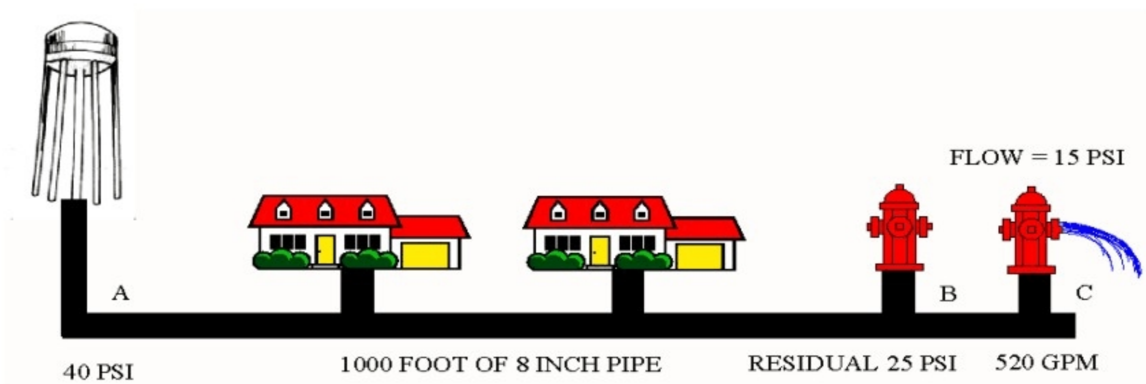

Figure 7 - Residual Pressure

Figure 8 - Flow pressure

EXTINGUISHING METHODS USING WATER

Water is considered a versatile extinguishing agent because of the ways it is able to extinguish a fire. Some of these are listed below.

- Cooling - lowers the temperature of burning fuel below its ignition temperature & quenches any surface fire by soaking into the burning surface of the material
- Smothering - if material is heavier than water, water will be on top and not allow oxygen to join with burning vapors, or when used with foam
- Emulsification - the blending of liquids that are not miscible, through agitation
  - Used to control fires in very heavy fuel oil fire (#6 fuel oil, crude oil)
  - Causes frothing which prohibits the release of vapors
  - Can be dangerous if not done properly
- Dilution - used in water soluble flammable liquids (alcohol)
  - Usually requires large amounts of water and can cause overflows
- Electricity and water
  - Water will conduct electricity due to impurities in its natural state
  - The breakup of a stream into small droplets will limit the amount of conductivity
  - Purer water will not conduct electricity
  - If person holding down hose is well grounded the chance of injuries is minimized

USING WATER ON SPECIAL HAZARDS

While most fires can be controlled by water, not all can. Certain materials may react to water in a violent manner or pose and extreme hazard to emergency service personnel. Some materials where care should be taken are listed below.

- Chemicals
  - May cause reactions that can release flammable vapors and heat (ammonium nitrate)
- Combustible metals
  - Can cause intense burning
- Radioactive material
  - May become contaminated and contaminate other items as runoff
- Gases
  - Primary extinguishing method is to stop flow of gas
  - Water may be used to disperse vapors
  - Water can be used to cool container and cool nearby combustibles when it is burning, but should not extinguish a burning column of gas
- Flammable liquids and gas
  - Cooling agent
    - Will work on high flash point liquids
    - Cut off release of vapors and disperse
    - Protect firefighting personnel
    - Cool exposed surfaces
  - Mechanical tool
    - Control leaks
    - Direct flow of liquid from an ignition source
  - Displacing medium (vapors and liquid)
    - Float oil above a leak in tank

STANDPIPE SYSTEMS [See Figure 9]

Standpipe systems have bee around over 100 years. In multi-story structures they have improved the fire department's ability to more quickly control fires on upper floors.. Standpipes are designed to provide a means of manual application of water on fire in large one-story buildings and high-rise buildings. Most buildings over four stories have standpipes and high-rises beyond the reach of aerial devices they are designed to either supply small diameter hose used by the occupants or large hose used by the fire department. For design and installation information you can reference NFPA Standard 14.

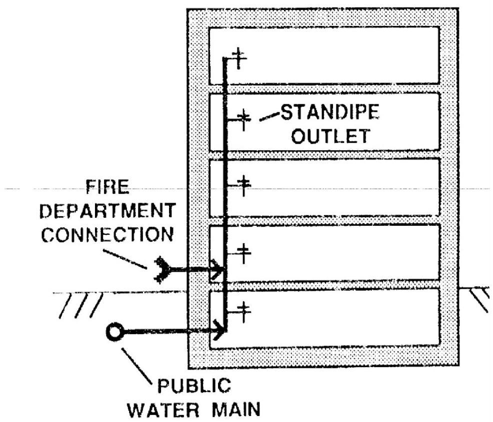

Figure 9 - Typical Standpipe System

There are three classes of standpipes. The classification is based on water application, supply, and who will use it. The classes are listed below

Class I standpipe

- Primarily used by fire department personnel
- Has 2 ½ " hose connections
- Used by trained personnel
- All portions of building within 30 feet of nozzle using 100 feet of hose
- Water supply must be for 30 minute duration

Class II standpipe

- Used for small streams
- Used by building occupants
- Used for incipient fire
- Used 1 ½" connections
- 30 minute duration water supply

Class III standpipe

- Combination of classes I & II
- Has 2 ½" outlet with 1 ½" adapter
- Water supply requirements are same as class I

The standards require a *pressure regulating device* when discharge pressures exceed 100 psi the pressure regulating device limits pressure to 100 psi. The standards also require Class I & III to have fire department connections [Stand Pipe Siamese]. The fire department connections must indicate on connection that it is for the standpipe, so it will not be confused with a fire department connection for an automatic sprinkler system.

WATER SUPPLY BASICS.

One of the reasons life exists on earth is because of the abundance of water. The amount of water has not change in hundreds of millions of years. Water may exist in different states [solid, liquid, gas] but the actual amount has not change. This is due to the ***Hydrologic cycle***. In this cycle the water evaporates off the surface, it condenses in to clouds and falls as rain. The cycle then continues.

Water supply systems have been around since ancient Rome. The Aqueducts of Rome was an early water supply system based on the 4th principle of pressure. After the fall of Rome in the 4th century A.D. these systems fell in to disuse. It wasn't until the early 19th centurty that we find the use of water supply systems in American cities. Water supply systems get their supplies from one of two sources,

- Surface supplies (lakes, rivers, reservoirs, oceans, etc.).
- Ground water supplies (wells and springs).

There are three types of water systems. These are gravity type, direct pumping, and a combination system.
The Gravity system delivers water directly to the distribution system without the use of mechanical equipment. It delivers water from the source directly to the distribution system without the use of pump equipment. Pressure in the system is provided by the elevation of the source from the distribution system. This is accomplished due the *4th principle of pressure* **[See Figure 10]**
Direct Pumping system uses pumps at the source of supply and delivers water into the distributing system. It is used when water cannot be sufficiently obtained from an elevated water source. Pumps are usually located by the water source. Pressure in the distribution system is provided by the pumps instead of the elevated water source **[See Figure 11]**
Combination Systems are a combination of gravity and pumping system. These are the most commonly used in the United States. Water is provided from a water source and pumped to water storage areas. This provides water for times of peak demands, such as, when fire departments are fighting fires. This system combines the best of the other two systems. Water can be pumped directly into the distribution system with any excess sent to the storage tanks. Pressure in the system is provided by both the pumps and in low pressure areas by the pressure in the storage tanks. **[See Figure 12]**

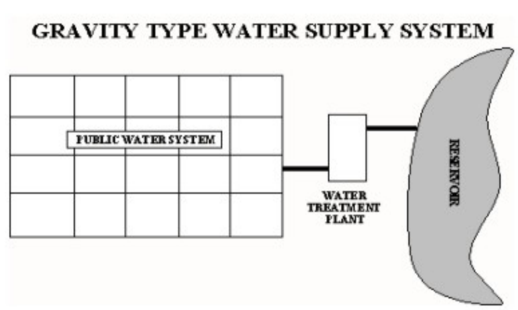

Figure 10 - Gravity Type Water System

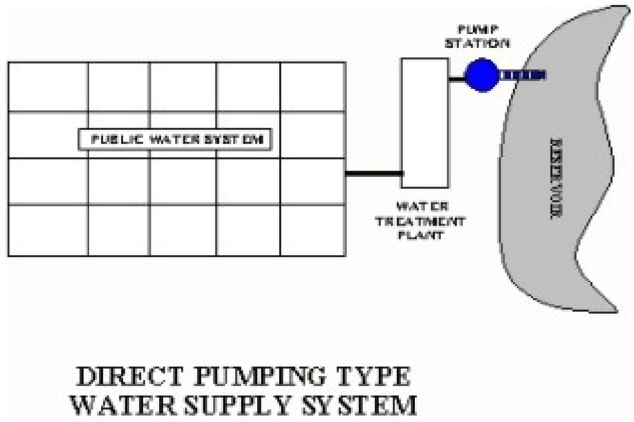

Figure 11 - Direct Pumping System

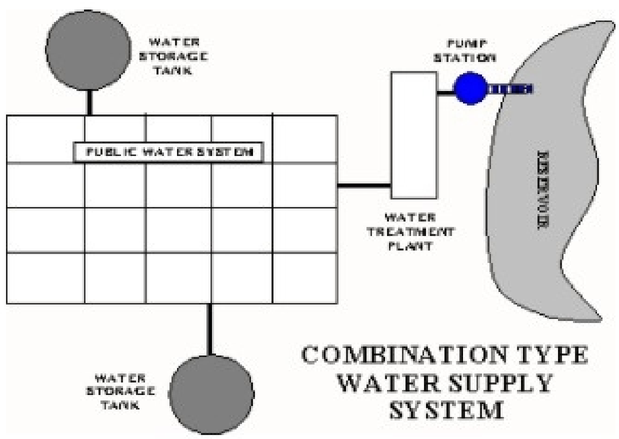

Figure 12 - Combination System

Pipelines [See Figure 13]

All water supply systems deliver their water through a series of pipes. These pipes designed to withstand pressure and to distribute water to the point of use. There are three classes of pipes in the system :

- ***Primary feeders*** consisting of large pipes which convey large quantities of water to smaller mains at various points of the system. Diameters range from 16" to 60" or greater.
- ***Secondary feeders*** forming the network of pipes of intermediate size reinforcing the various loops of the primary feeder system. Diameters range from 12" to 16".
- **Distributors consisting** of a grid arrangement of smaller mains serving the individual fire hydrants and blocks of consumers. Minimum diameter is 6", but the rapid trend is toward 8".

Water supply systems capability. Is based on several factors. Size of the pipe is one, and how the pipe is fed water is another. The main idea is to provide water through an entire system with as little or no loss in pressure or volume if possible.. The direction of water flow and threefore its effectiveness are based on the main typs. There are basically three ways to accomplish ths. These are described below from the least effective to the most effective:

- *Single main* is a dead end. Fed from one direction, similar to single hose line.
- *Looped main* is fed from two directions, similar to parallel lines. Half the total flow in each reduces the friction loss by 4 times.
- *Grid system* is fed from four directions, similar to 4 parallel lines. One quarter the flow in each reduces the friction loss by 16 times.

MINIMUM SIZE PIPE FOR WATER MAINS.

The size of the water main in inches of diameter will have an impact on the volume of water flowing anf the amount of pressure lost to friction loss. Years ago supply pipes could be as small as 4 inches in diameter. Today the minimum diameter is 6 inches at most, and 8 inches is usually preferred.

- Residential districts: 8", however 6" may be used with a good grid system, cross-connected at intervals not exceeding 600'.
- Shopping centers and industrial areas: 12" or larger depending on size, layout and occupancy of structures. 8" may be used with a good grid system.

FACTORS THAT AFFECT CARRYING CAPACITY.

When water pipes are new and when they have little or no bends in them they will be most efficient. As pipes get older and materials are deposited in them they become less efficient. We usually determine efficiency by a pipes water flow capacity. Some of the things that can affect this are:

- Incrustation - growths on the total interior surface of the iron pipe caused when water comes in contact with iron and gradually causes a restricted diameter.
    - Caused by tubercular corrosion or rust (tuberculation).
    - Caused by the chemical constituents of the water.
    - Caused by growth of biological or living organisms.
    - Remedied by the use of cement-mortar lined pipe.
- Sedimentation - deposits formed on bottom of the pipe's interior surface.
- Valves - completely or partially closed.
- Other variables in a water system that affect available water:
    - Size and length of mains.
    - Cross connections.
    - Static pressure.

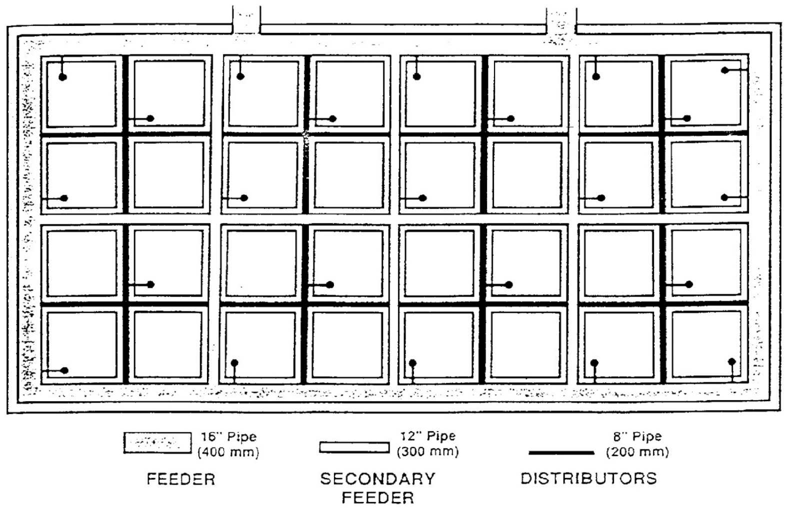

Figure 13 - Typical Water Supply System

FIRE HYDRANTS.

Fire hydrants have been around for about 200 years. In the colonial days when a fire occurred the fire department would respond and in order to get water from the water mains under the streets they would dig a hole in the street and cut a hole in the wooden water main. The hole would fill up with water and the fire department would use this to fight the fire. When they were finished they would place a "plug " in the water main and mark the place where they put it. This would make it easier the next time they needed water. When hydrants would replace this system of placing plug, the term "fire plug" remained. Today many firefighters still refer to a hydrant as a "fire plug". Fire hydrants of the post-type as used today first appeared around 1800. **[See Figure 14]**

Types of Fire Hydrants.

Wet-barrel type **[See Figure 15]**

The wet barrel hydrant is used in areas where freezing does not occur. You will typically find them in the Southwest part of the United States. The parts of wet-barrel hydrant are:

- Operating nut - turns hydrant on and off
- Bonnet - top of the hydrant
- Barrel - main body of hydrant, contains operating stem
- Discharge outlet - where fire hose is hooked up to allow water to flow from hydrant

Dry-Barrel Type [See Figure 16 & 17]

The dry-barrel hydrant is used in areas where freezing temperatures occur. This type is found in most of the northern United States.. The parts of dry-barrel hydrant are:

- Operating nut - turns hydrant on and off
- Bonnet - top of the hydrant
- Barrel - main body of hydrant, contains operating stem
- Discharge outlest - where fire hose is hookedup to allow water to flow from hydrant

Figure 14 - Early Fire Hydrant

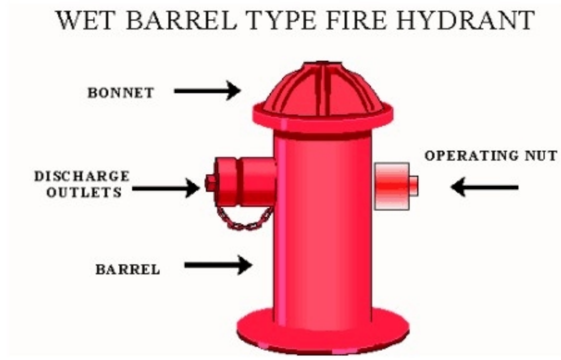

Figure 15 - Wet-Barrel Hydrant

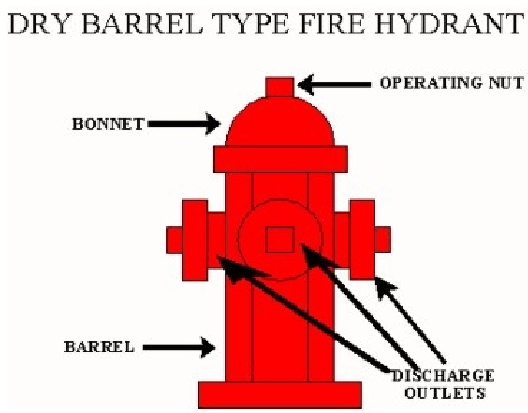

Figure 16 - Dry Barrel Hydrant

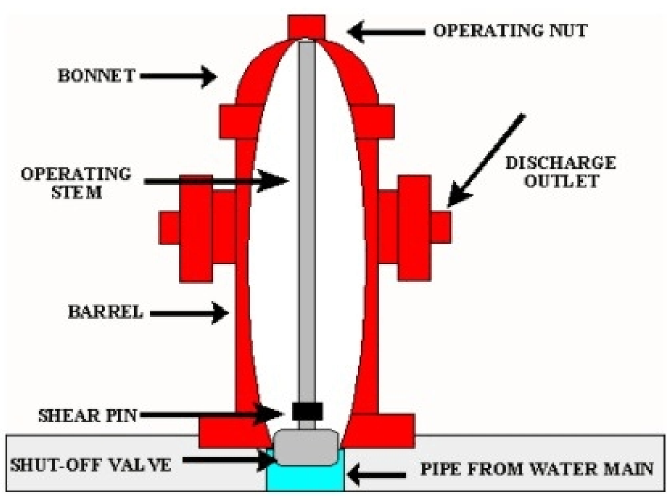

Figure 17 - Parts of Dry-Barrel Hydrant